

Fourth Annual Conference on Carbon Capture & Sequestration

*Developing Potential Paths Forward Based on the
Knowledge, Science and Experience to Date*

Geologic - Monitoring, Mitigation, & Verification (2)

Instrumentation of Deep Monitoring Well at the Pennwest Petroleum's Violet Grove CO₂-EOR Pilot in Alberta, Canada

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Outline of Presentation

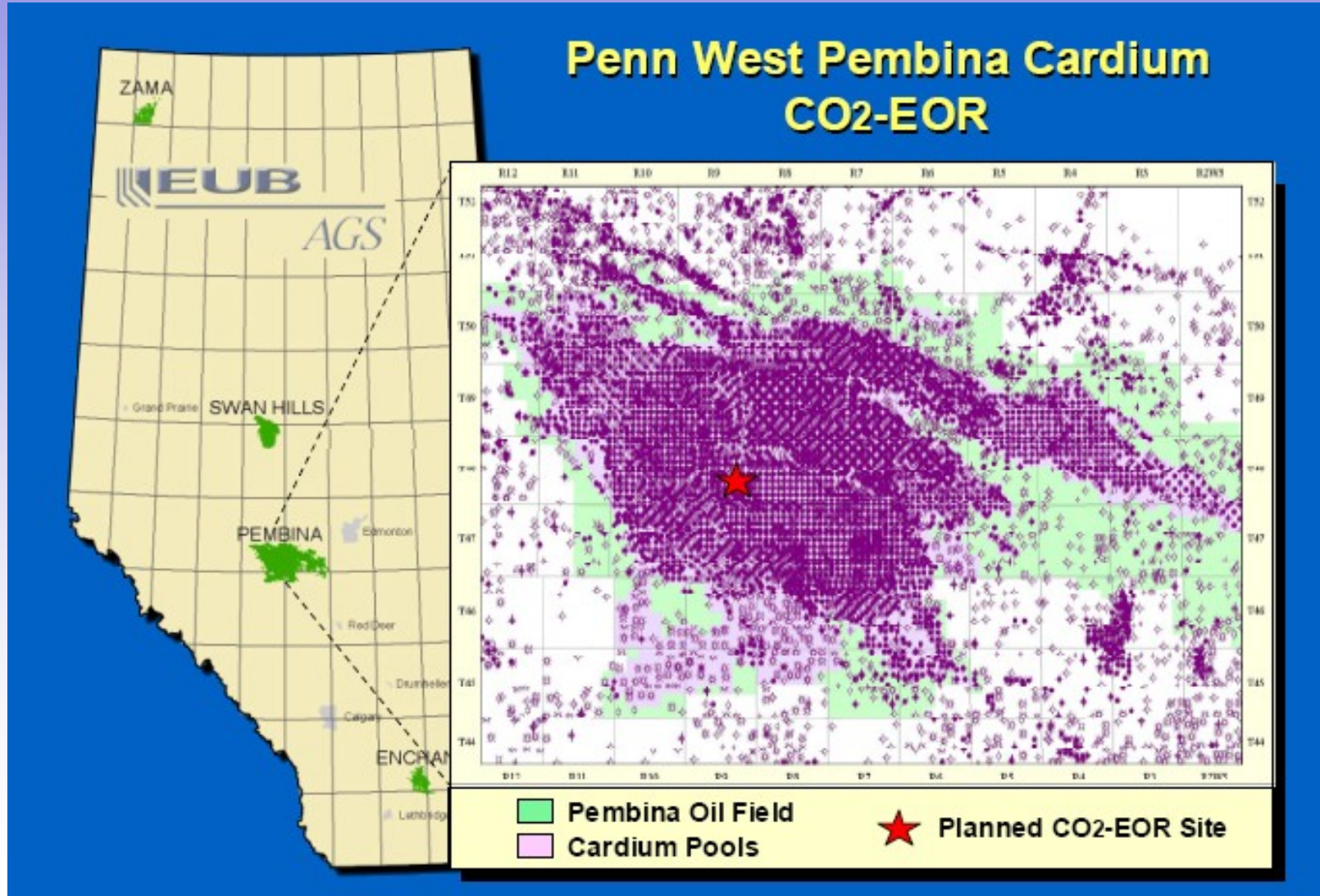
- Background
- Brief Description of Violet Grove CO₂-EOR Pilot
- Overview of Instrumentation Well Design
- Installation History
- Cementing Data
- Current Status of Project

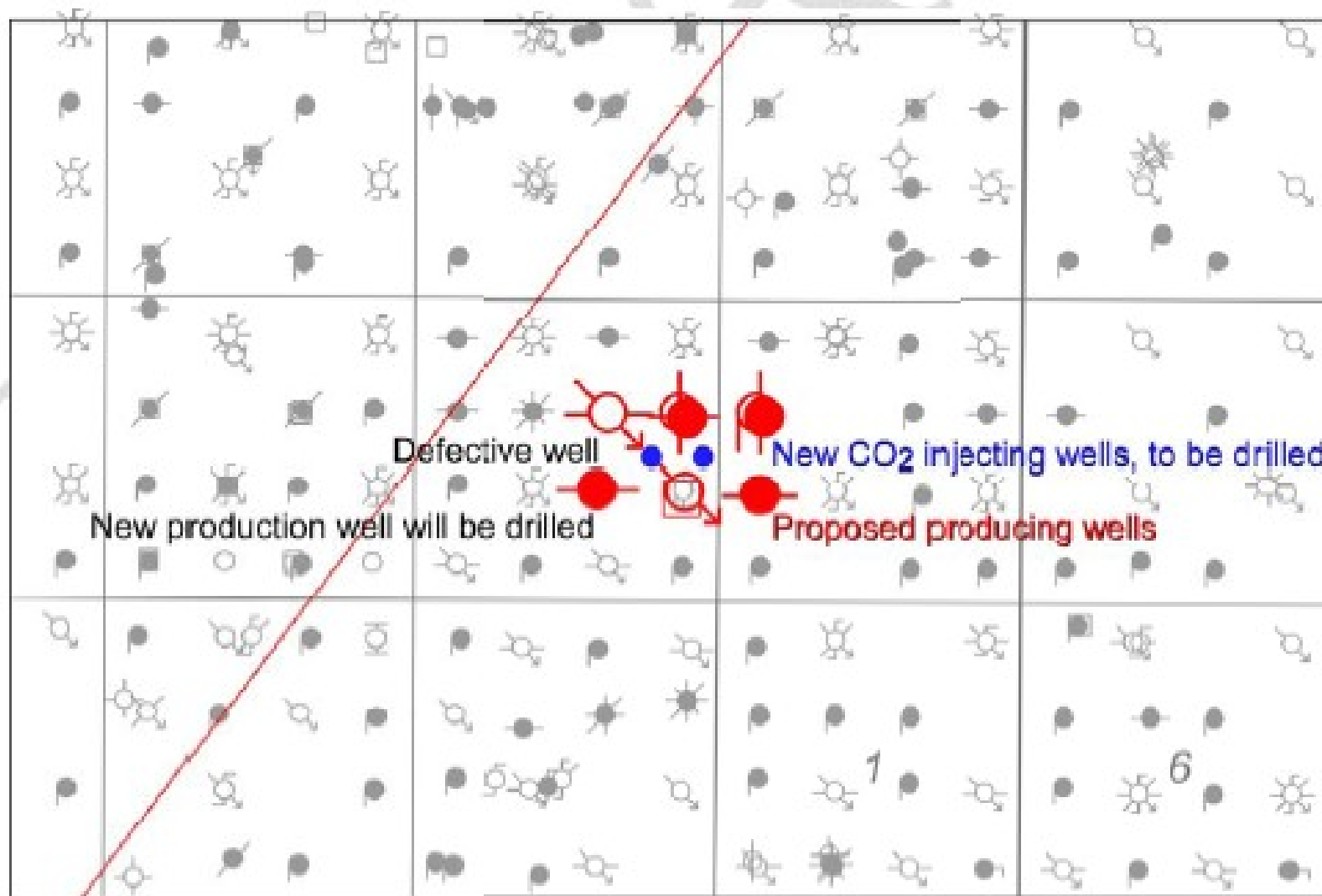
Background

- To encourage the development of a CO₂-storage industry in Alberta toward reducing Alberta's CO₂ emissions into the atmosphere, the Alberta Department of Energy (ADOE) instituted a Royalty Credit Program that offered a royalty reduction to energy companies that use CO₂ in enhanced oil recovery. Four companies that were starting pilot operations in the fall of 2004 were successful in their application:
 - Apache at Zama in northwestern Alberta,
 - Devon Energy at Swan Hills in central Alberta,
 - Penn West at Pembina in southwestern Alberta, and
 - Anadarko at Enchants in southeastern Alberta.



Pennwest Petroleum's Violet Grove CO₂-EOR Pilot

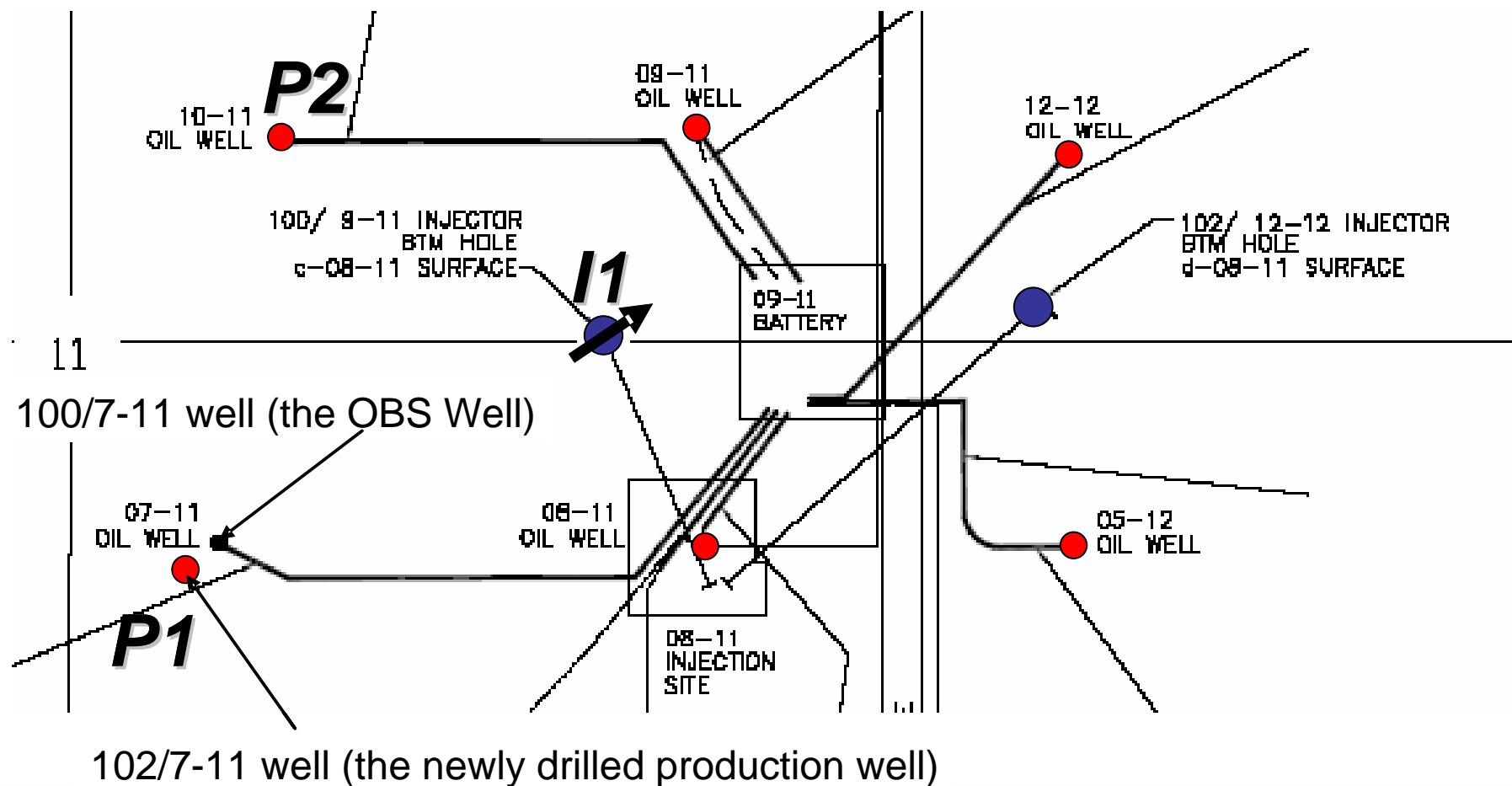




T48

R9W5

R8



CO₂-EOR Pilot Conditions

- Previous reservoir history included primary and waterflooding (injected water was fresh)
- Inject food grade CO₂ (~ 35t/well/day) from Rimbey gas plant through two new directional wells drilled from the same pad. Some recycling of CO₂ . No water-alternating-gas injection.
- Pilot length is two years of injection plus and an additional 1 to 3 years of production.
- 20 acre spacing, two injectors and 6 producers. Breakthrough on the on-trend direction is expected in 6 months.
- Access is excellent (1 hr Edmonton, 3 hrs Calgary).
- Perforations concentrated in upper and middle sand. 50 tonne fracs in all 8 wells, in some cases they are refracs They connect all three sands. Expect production from all three sands but dominantly from upper two sands due to perforations placement and permeability distribution.

CO₂-EOR Pilot Conditions

- Downhole pressure/temperature gages on the injection wells
- The oil does not contain CO₂, so the injected gas will be traceable.
- extensive fluid monitoring from all production wells (primarily to monitor issues with scaling, corrosion and paraffin) and geochemistry monitoring program.
- Penn West will be taking a sponge core which will be accessible for further testing. There is additional core in storage. They will allow additional core to be taken for samples of bounding seals, if required. Additionally, they are open to taking cement samples from an old well to evaluate their stability.
- Geophysical logs of standard suites will be made available. They will consider sharing costs of cased hole neutron, dipole sonic and FMI.
- Penn West has 100% interest on the lease.
- Huge potential for expansion to the entire Pembina Cardium field, the largest oil field in N. America, with 8000 wells to date, where Penn West is a partner in 65% of the field, and operates ~35%.
- 100 Km from Red Deer, Fort Saskatchewan and Wabamun, three of Alberta's 4 CO₂ hubs.

Alberta Energy Research Institute/Pennwest Violet Grove Monitoring and Verification Program

Baseline Studies

EUB Data Retrieval (LS)
EUB Data Retrieval (RS)
Well Analysis (LS)
Well Analysis (RS)
Baseline Geology (Local Scale=LS)
Baseline Geology (Regional Scale=RS)
Baseline Hydrogeology (Local Scale)
Baseline Hydrogeology (Regional Scale)
Baseline 2D Surface Seismic & VSP
Instrumentation of the Deep Monitor Well
Drilling of the 3 to 5 Shallow Monitor Wells
Monitoring of Existing Local Water Wells
Soil Gas and Casing Gas
Chemistry Water Prod. Primary Recovery
Core and Reservoir & Fluids Analyses
Well Tests
Rock Physics
Well Log Suites
Wellbore Integrity
Baseline Modelling

Continuous Monitoring

Monitoring data Penn West
Geochemistry at Production Wells
Pressure & Temperature Deep Monitor Well
Passive Seismic

Discrete Monitoring

Time-lapse VSP and surface seismic survey
Casing Gas & Soil and Gas Sampling
Fluids from Shallow Monitor Wells
Fluids from Deep Monitor Well
Well Testing and Tracers

Continuous Integration

Reservoir Modeling
Geochemical Modelling
Integration Continuous-Discrete Monitoring
Post-Pilot Program
Final Reporting
Contingency Plans
Project Management

Observation Well Specifications

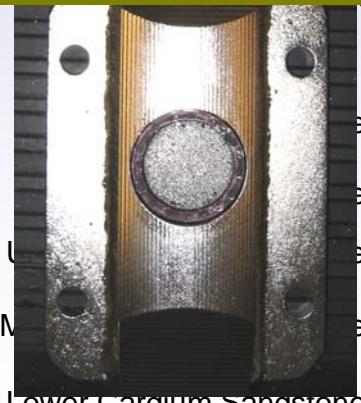
- Well depth: 1600 m (5250 ft)
- Casing: 139.7 mm @ 25.3 kg/m
- BHP: approximately 19 MPa (2700 psi)
- BHT: approximately 50°C
- Deviation: none (vertical well)
- Other: well is sweet

Geology and Design Completion

**3 downhole
fluid sampling
ports**



**8 phone
Geophone
string**



Lower Cardium Sandstone

Ground Surface 0

1023

1.4

1599

1619
1619.5

1622

1630.5

1637.2

1360
1380
1400
1420
1440
1460
1480
1500
1520
1540
1560
1580
1600
1620

8 Geophone String. Bottom phone at 1640 mD and phone spacing is 20 m.

Fluid Sampling Port #2 at 1622 mD. Port located within Upper/Middle Cardium SST

**3 pairs of
pressure/
temperature
gauges**

on for Obs Well (100/7-11-48-9W5)

ling tubing. The tubing is run to surface. From surface to d with ... on strapped to ... tubing string.

Top at ...

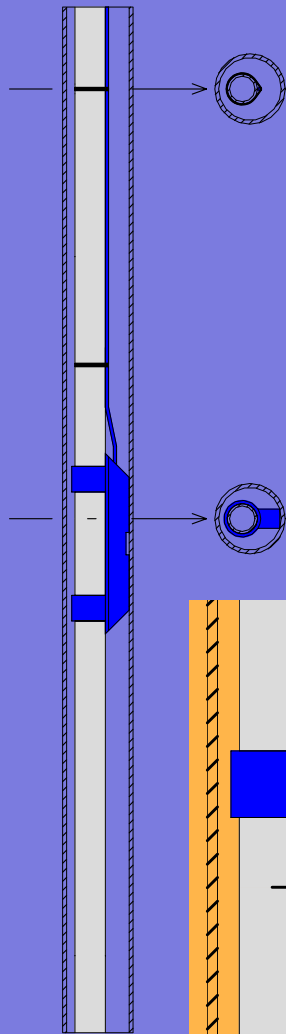
g Port #1
Port located within ... zones where ... %

Two (2) pressure gauges at 1602 mD

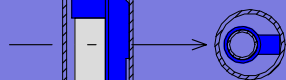


Two (2) pressure/temp. gauges at 1610 mD. In the middle of the Cardium Zone.

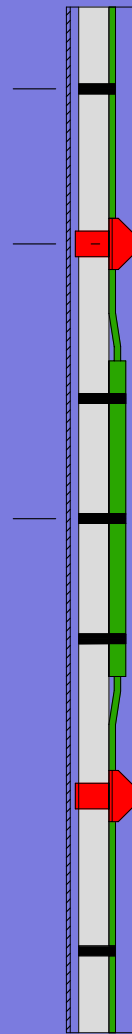
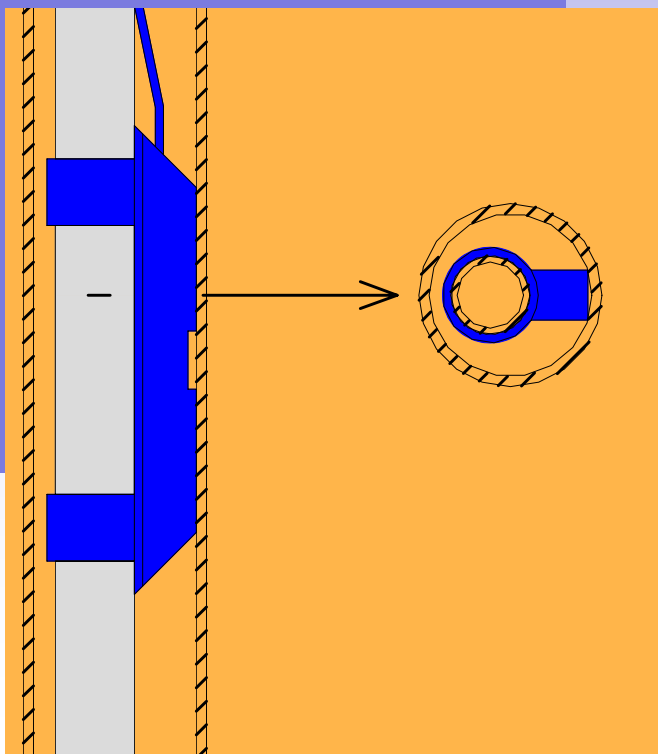
Two (2) pressure/temp. gauges at 1621 mD.



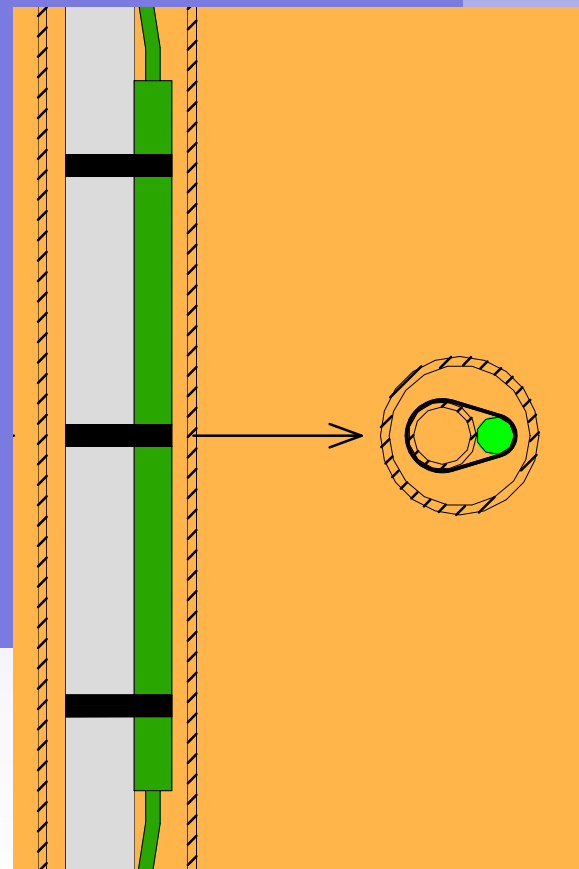
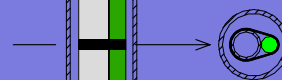
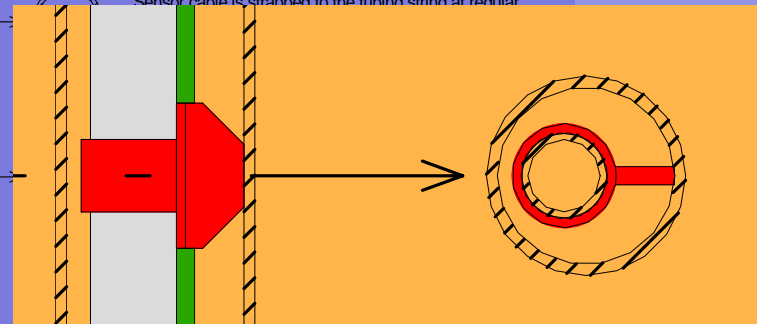
Each pressure/temperature sensor has its own signal cable that must run to surface. It is banded to the tubing string at regular intervals.



Pressure/temperature sensor assembly is rigidly clamped to the tubing string. The pressure sensing point is located near the casing wall. No additional shark fin is required for this assembly.



Sensor cable is strapped to the tubing string at regular



Preparation Work Prior to Field Installation



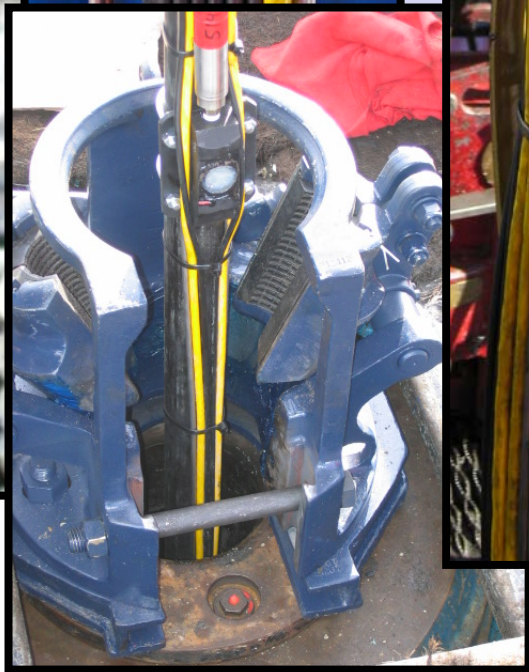
Tuesday, February 22, 2005



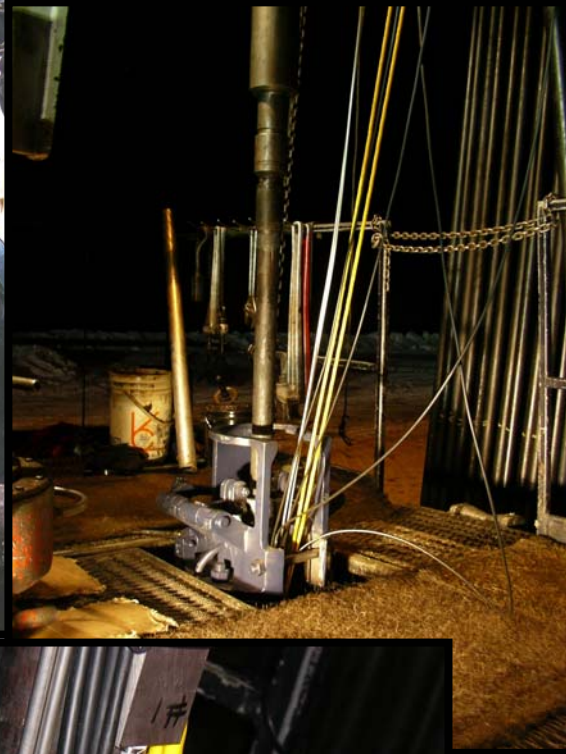
Wednesday, February 23, 2005







Thursday, February 24, 2005





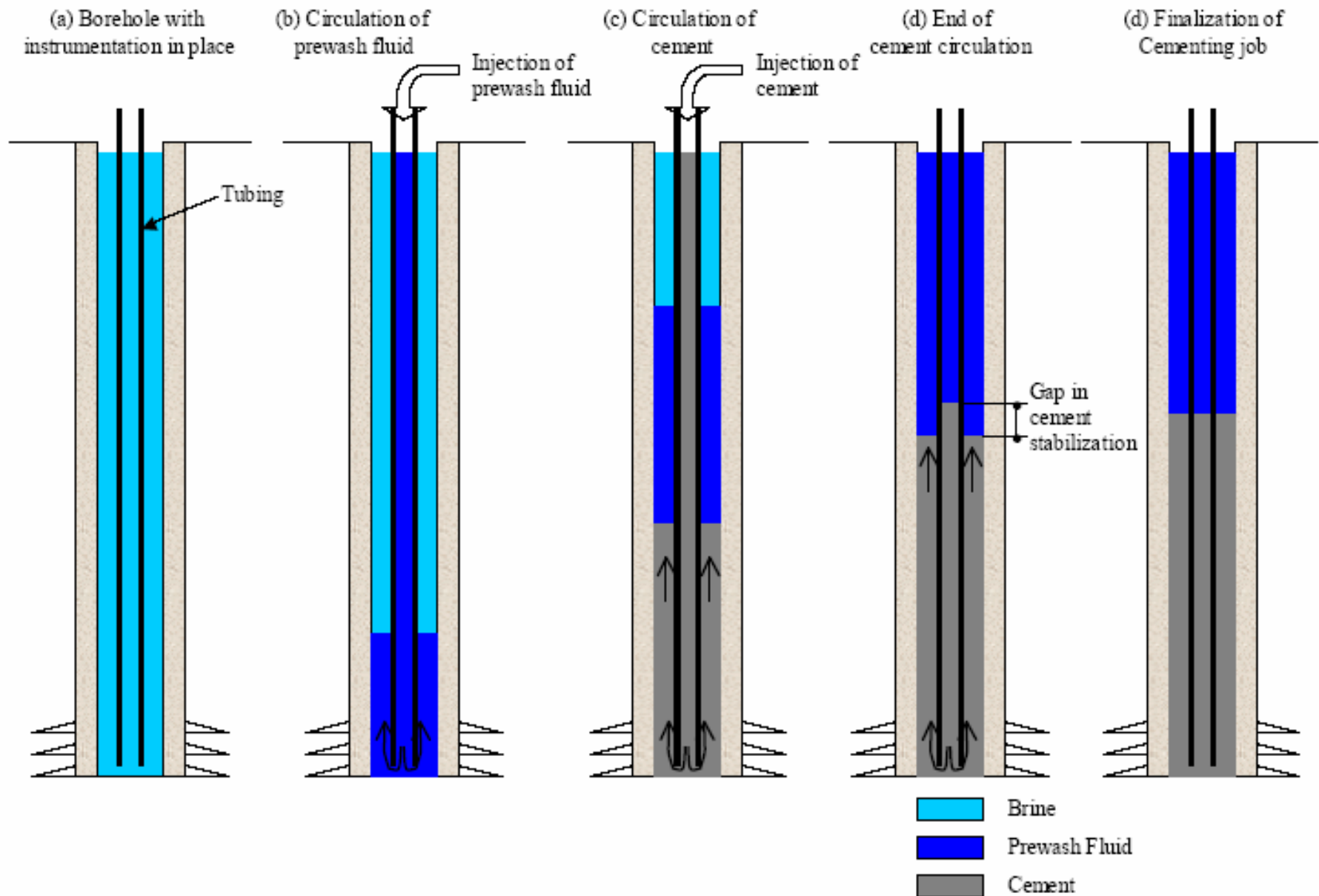
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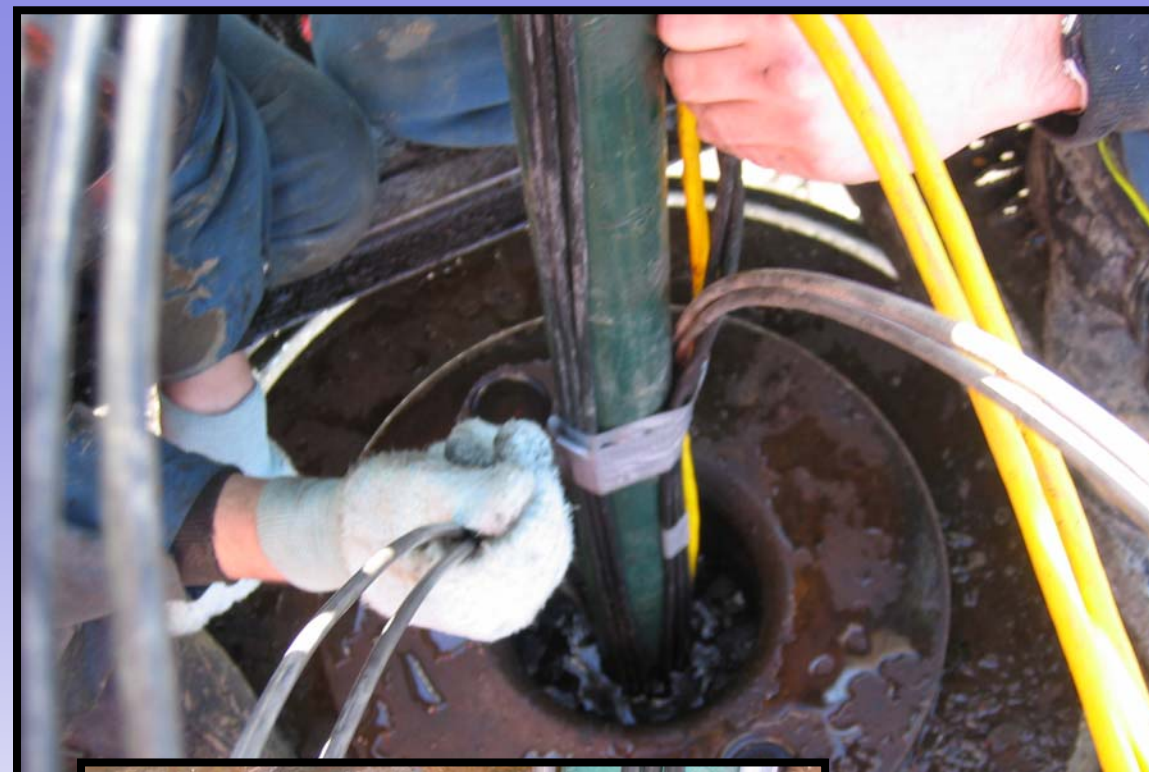


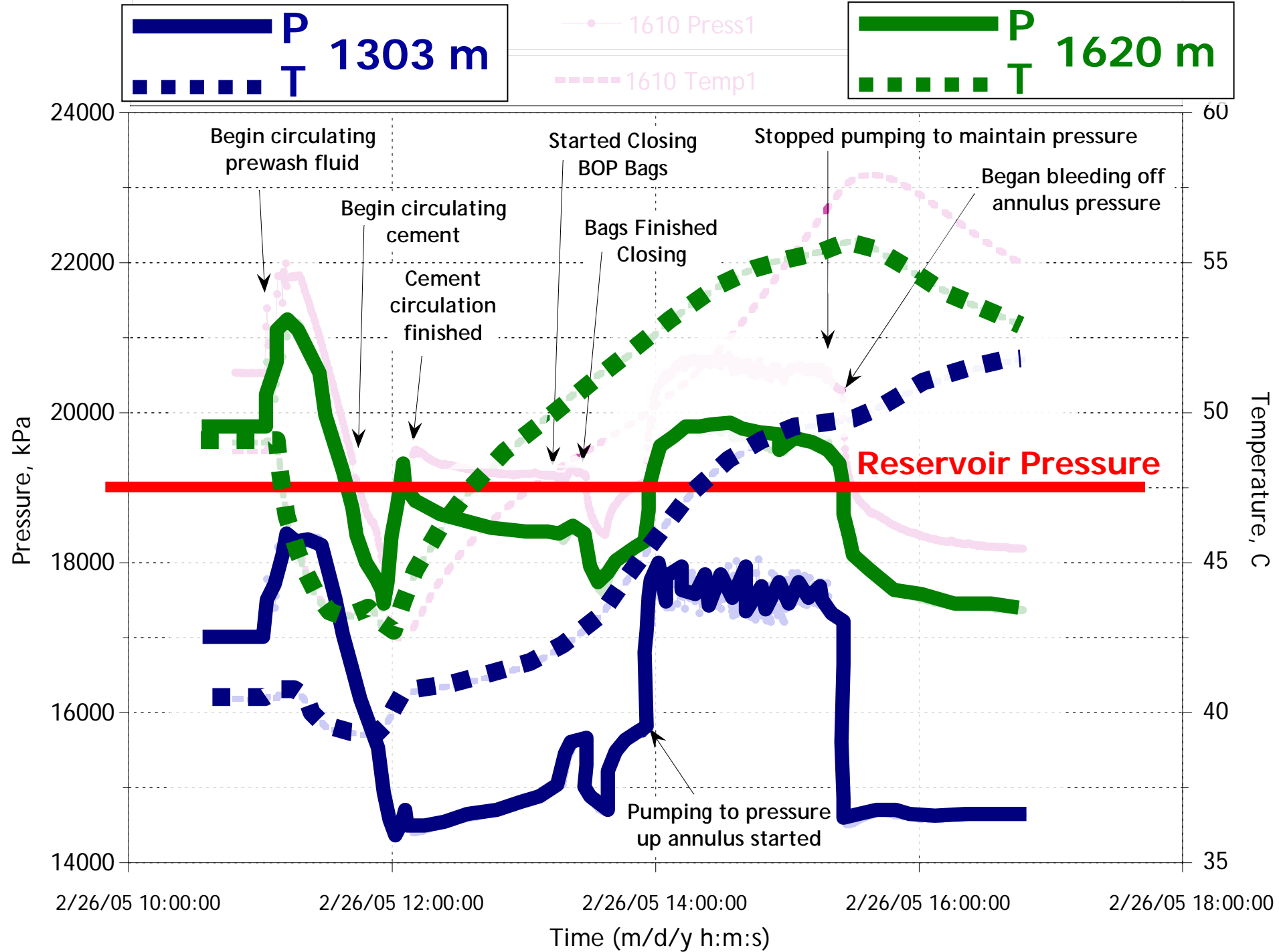
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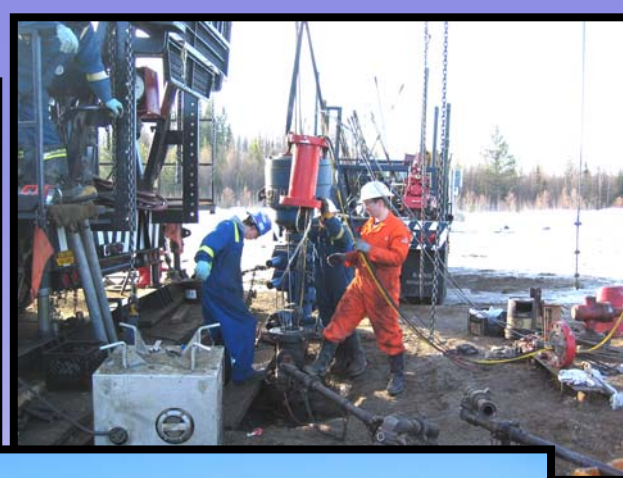


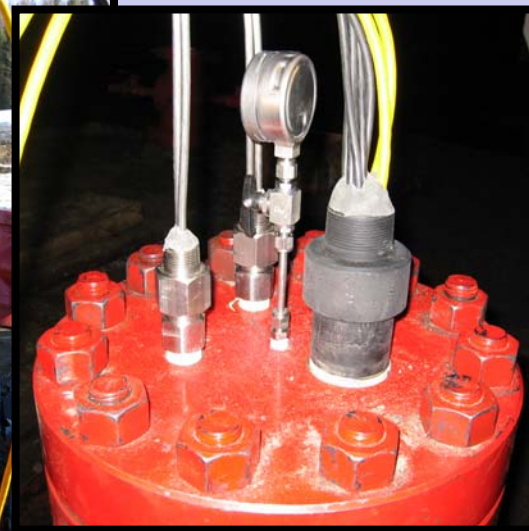
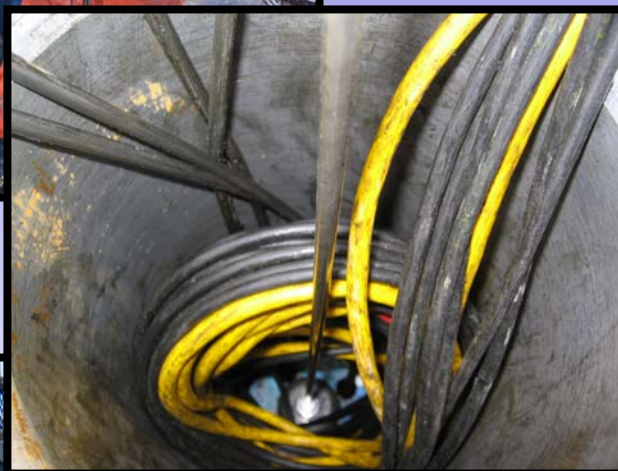
Cementing of the Observation Well











Questions?

Pennwest Petroleum's Violet Grove CO₂-EOR Pilot Project



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Chalaturnyk, R., Wichert, G., Gunter, B., Lawton, D., and Bachu, S.